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# **Wind Decision Support for UAS Operations**

**Jim Evans  
Senior Staff  
Air Traffic Control Systems Group**

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# Outline

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- **Operational needs**
- **Current capability for low altitude (below 500 ft AGL) winds information**
  1. **Forecasts (e.g., HRRR) plus ASOS**
  2. **FAA Weather Systems**
    - **Integrated Terminal Weather System (ITWS) for 34 major metropolitan areas**
      - Gridded winds analysis**
      - Wind shear phenomena (microbursts, gust fronts)**
    - **NextGen Weather Processor and CSS-Wx product distribution**
- **Experience with low altitude strategic (multi-hour lead time) wind forecasts for airport AAR decision support**
- **Suggestions for next steps**



# Assumptions about UTM

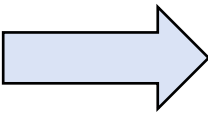
- **Traffic Management System for small UAVs (e.g., under 50 lb)**
  - Class G airspace: Up to 500 feet AGL
  - Fixed wing and rotor
  - Winds of concern for rotor and small foam fixed wing are 10-20 knots
- **Weather conditions for “routine” operation is an important factor**
  - Package/medical delivery, fire/police usage are likely to consider operation when precipitation is in the area (not necessarily on flight path)

Element	Operational Decisions	Available Data Sources
Wind @ launch altitude	Launch control	ASOS (10 m)
Wind @ cruise altitude (up to 500 feet)	Flight/trajectory control  Avoid wind phenomena of concern to vehicle (gust fronts, microbursts)  Planning for operations (e.g., trajectories, go- no go)	Radar (TDWR, WSR-88D, ASR), Rawinsonde, Aircraft (MDCRS), LLWAS, UAS(???)  Numerical forecasts (HRRR, RUC, RAP, etc)
Precipitation	Flight control; vehicle damage; interference with communication and/ or mission objectives	Weather and Surveillance Radars; Integrated Weather Systems (CIWS, CoSPA, NWP); numerical forecasts



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# HRRR model as a Baseline Decision Support System

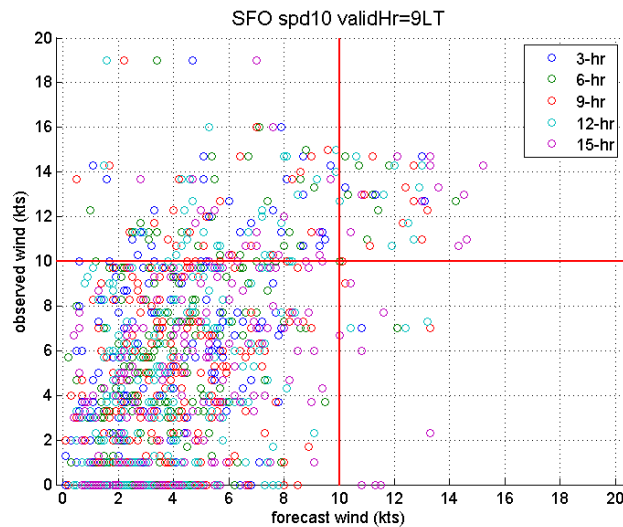
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- **NASA / Lincoln Lab consensus to use as a baseline forecast**
- **Provides a readily available generalized “solution”**
  - **Leverages numerical weather prediction R&D that has evolved for decades**
  - **Provides forecasts of nearly all relevant UTM weather elements**
  - **Coverage over entire CONUS**
- **Observed shortcomings (see next slides)**
  - **Skill diminishes at local scale, which may be a factor for UTM ops**
    - **Spatial scale of physics**
    - **Inherent “smoothing” of analysis field (observations) and forecast fields**
  - **Does not fully exploit high resolution information from recent observations in its shorter horizon forecasts (~ under 3 hours)**

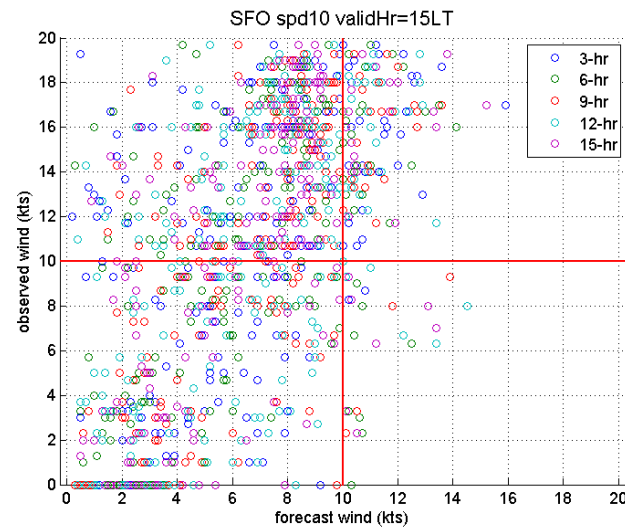


# Forecast bias observed at 10 m

## SFO observed 10-m wind (ASOS) versus forecast wind, all forecast horizons



9 AM forecast target



3 PM forecast target

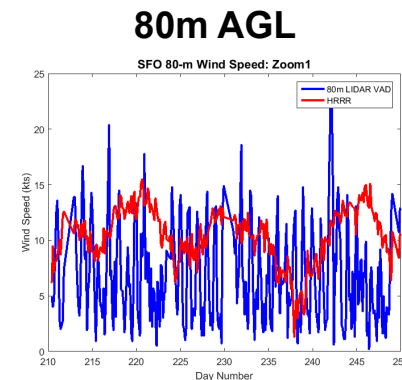
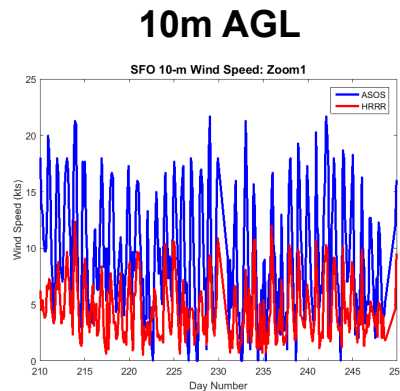
*HRRR substantially under-forecasting observed 10 m ASOS wind*



# Comparison of Observations and HRRR at 10 m and 80 m

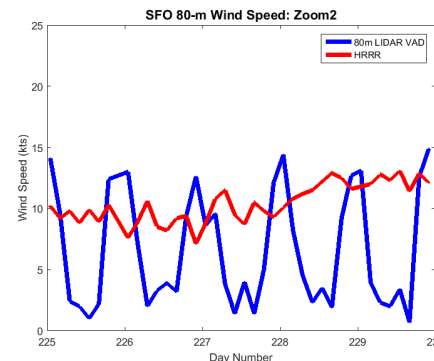
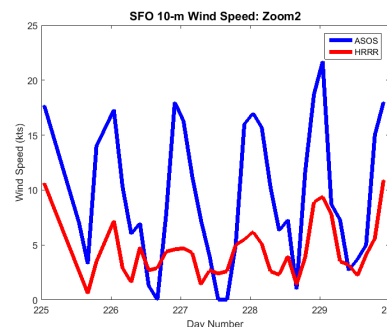
- There is a diurnal cycle in observed winds
- At 10m AGL: HRRR captures cycle, underestimates magnitude
- At 80m AGL: HRRR misses cycle, overestimates magnitude

40 day period:



80 m obs  
made using  
LIDAR

5 days period:



Blue – obs  
Red - HRRR



# Outline

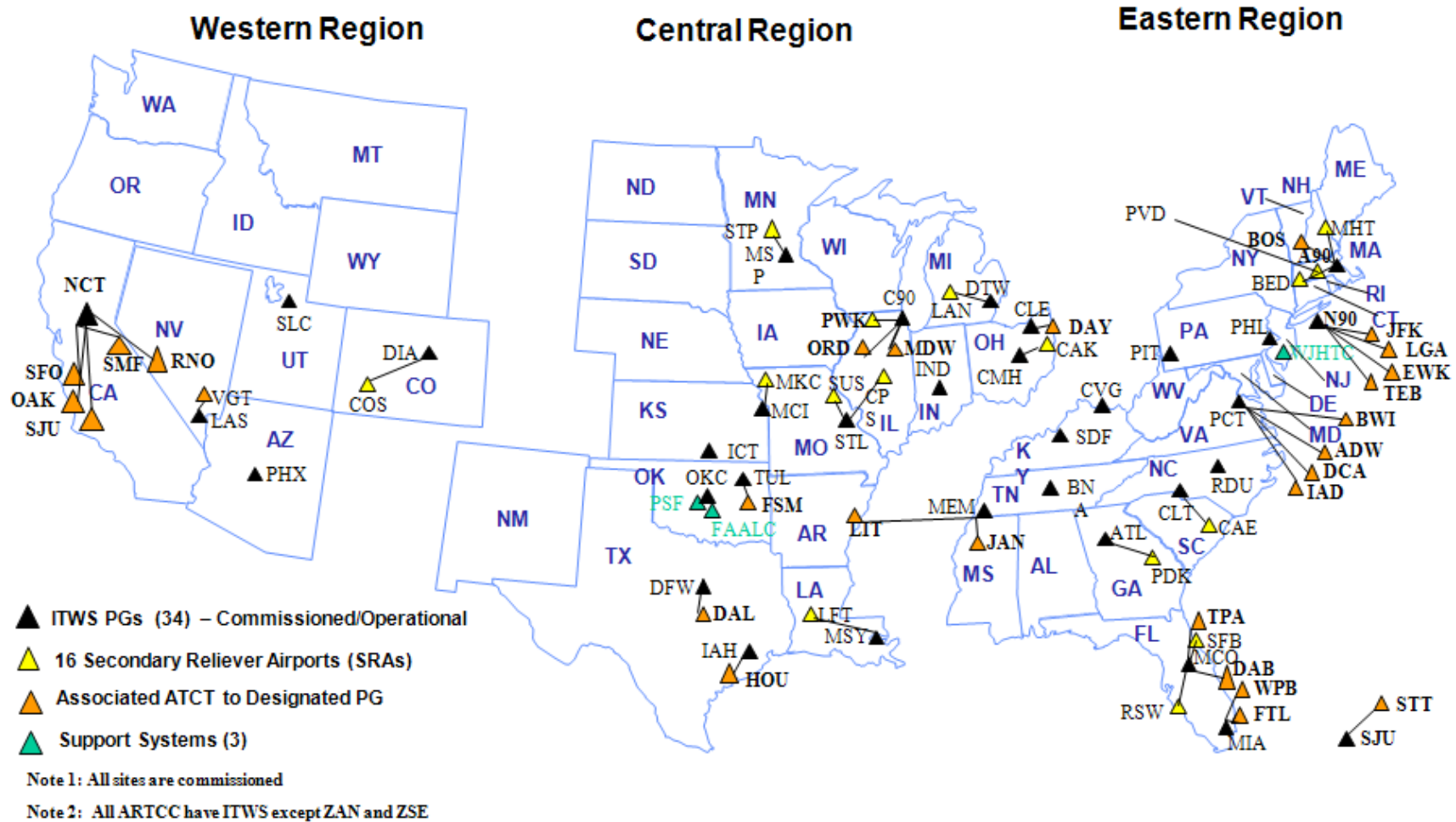
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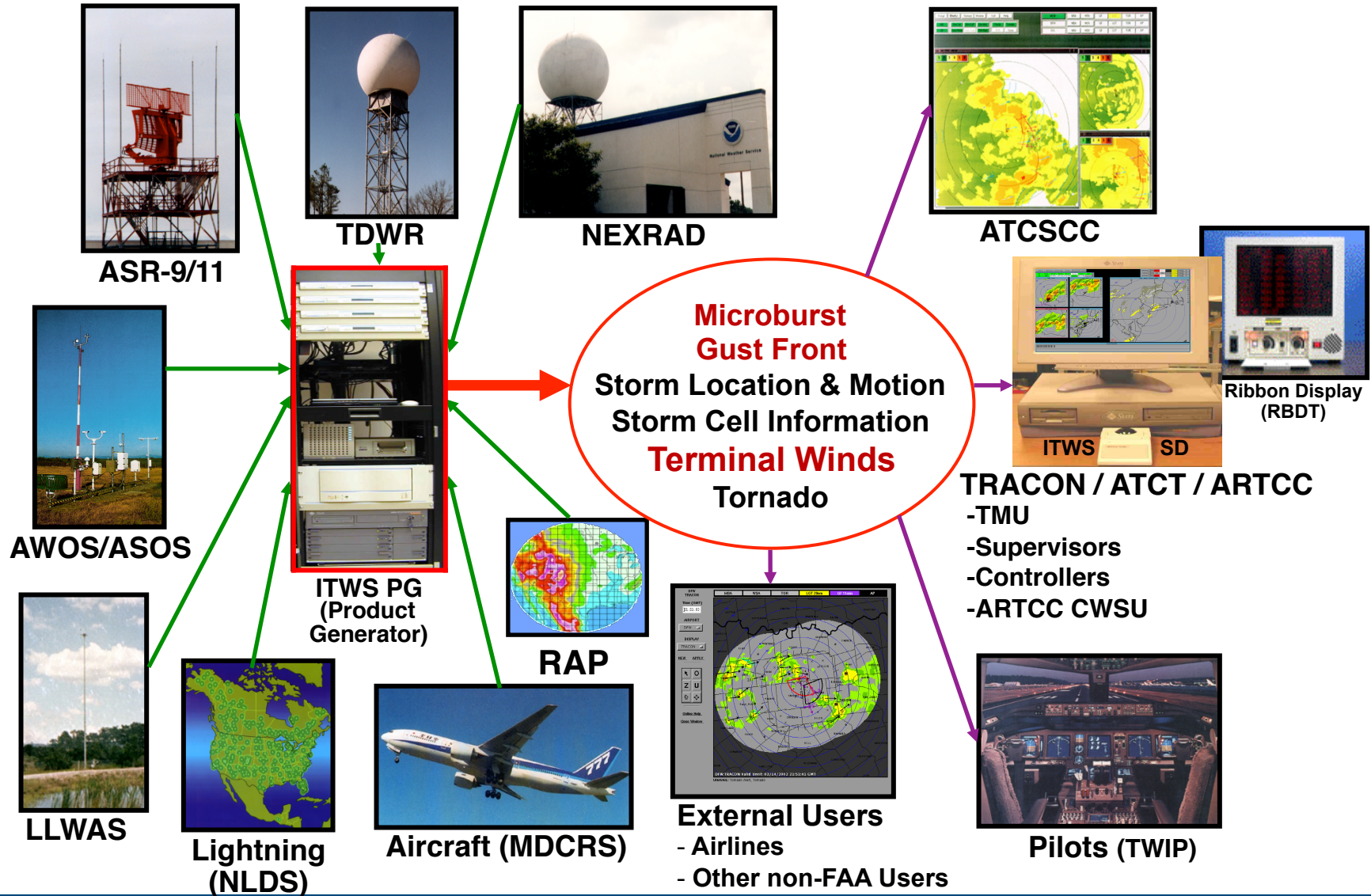


# Integrated Terminal Weather System (ITWS) Locations



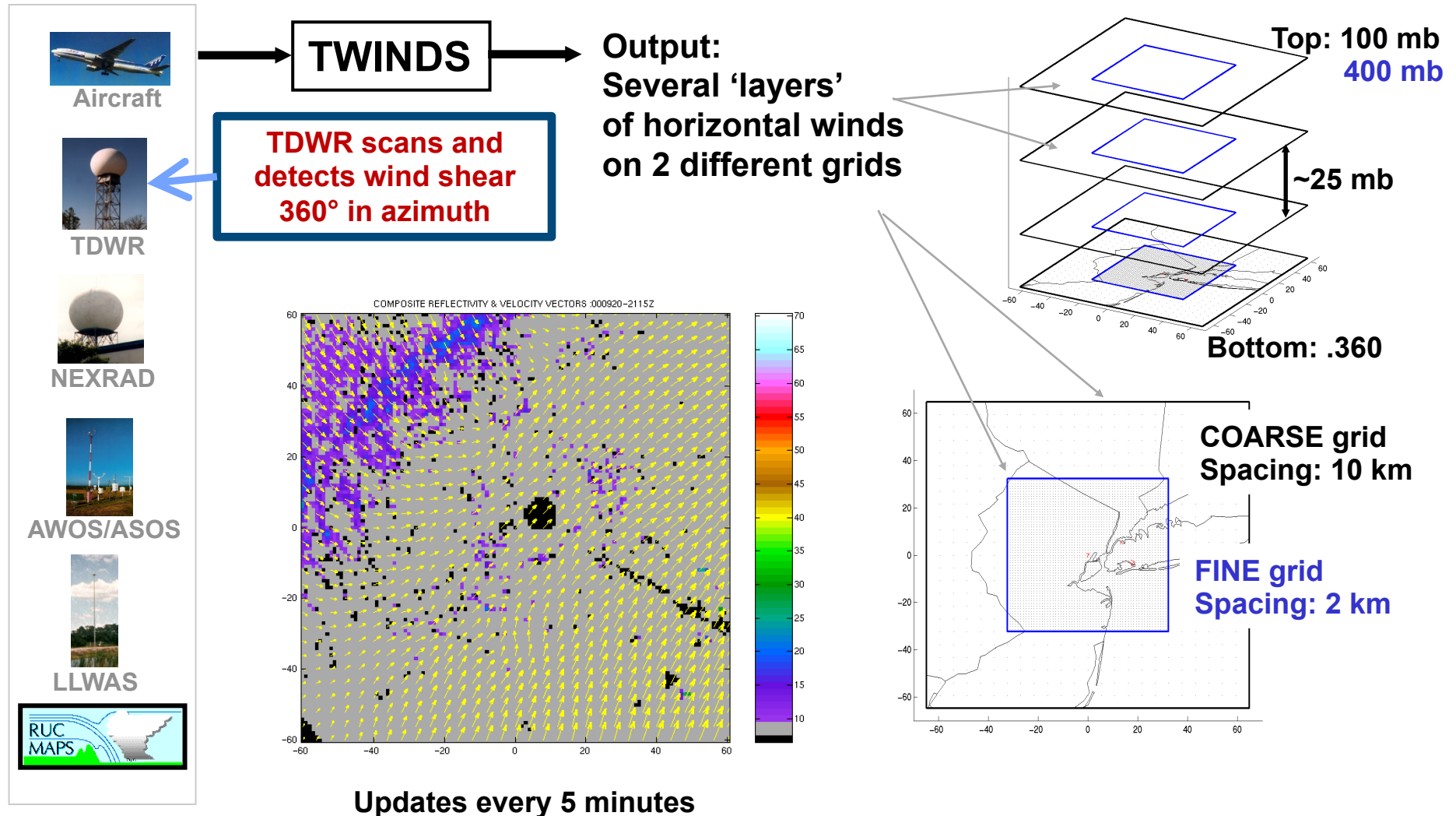


# Integrated Terminal Weather System (ITWS)



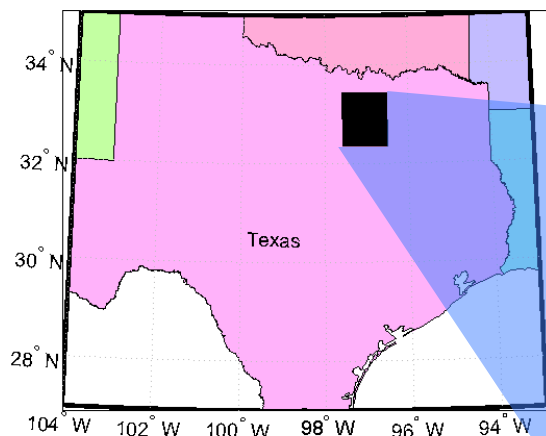


# Terminal Winds Analysis



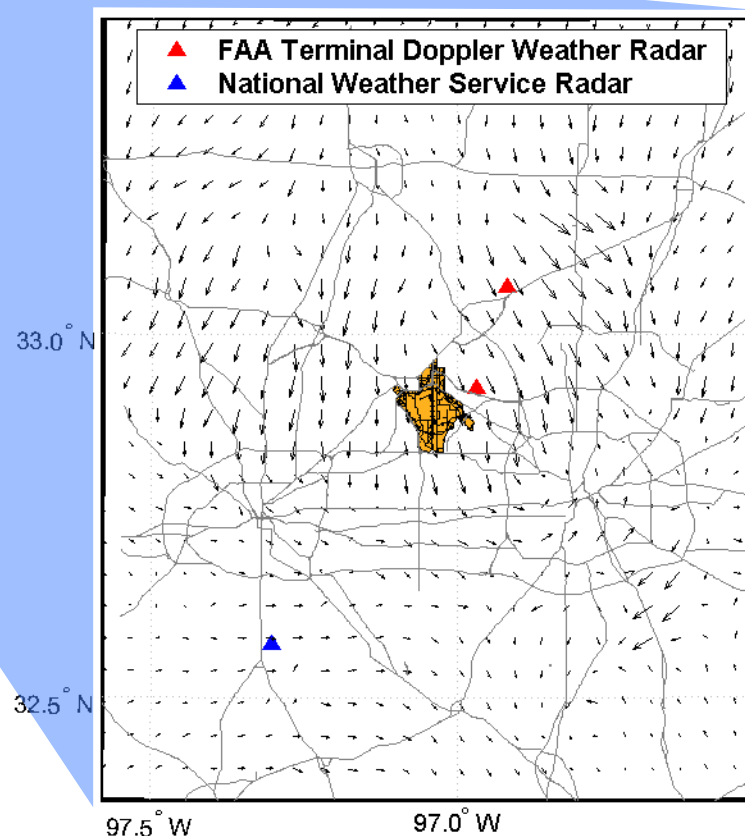


# Example—DFW Terminal Winds



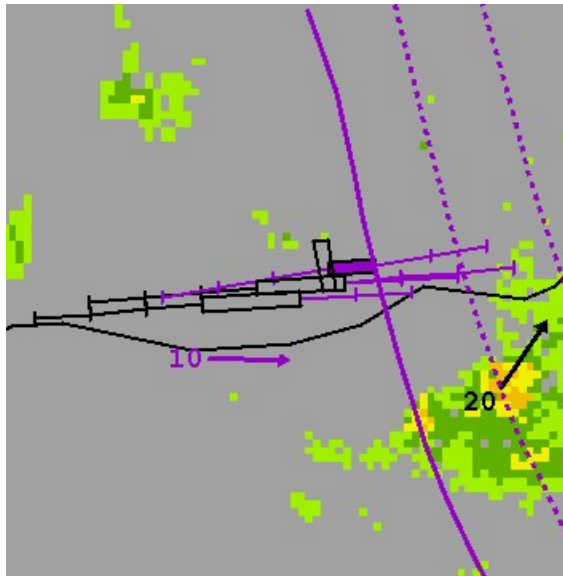
**Areas of fine grid winds**

TRACON	Area (x 1000 sq km)
Dallas	23
New York	40
Orlando	104
Washington Baltimore	112
Northern California	112





## Gust Front Product (ITWS, NEXRAD)



Gust Front  
17 min

Microbursts are detected by both TDWR and NEXRAD - range of coverage is 35 km from radar

Microbursts can create very strong winds a considerable distance from the rain core – see the back up information slide # 1

Solid purple line indicates current location of gust front. Dashed purple lines indicate estimated location of gust front 10 and 20 minutes in the future. **Purple arrow and number indicate direction and speed of wind behind the gust front.**

If a gust front is strong enough, it can generate a wind shear with gain alert on the ribbon displays and the alerted runways and/or runway extensions are purple.

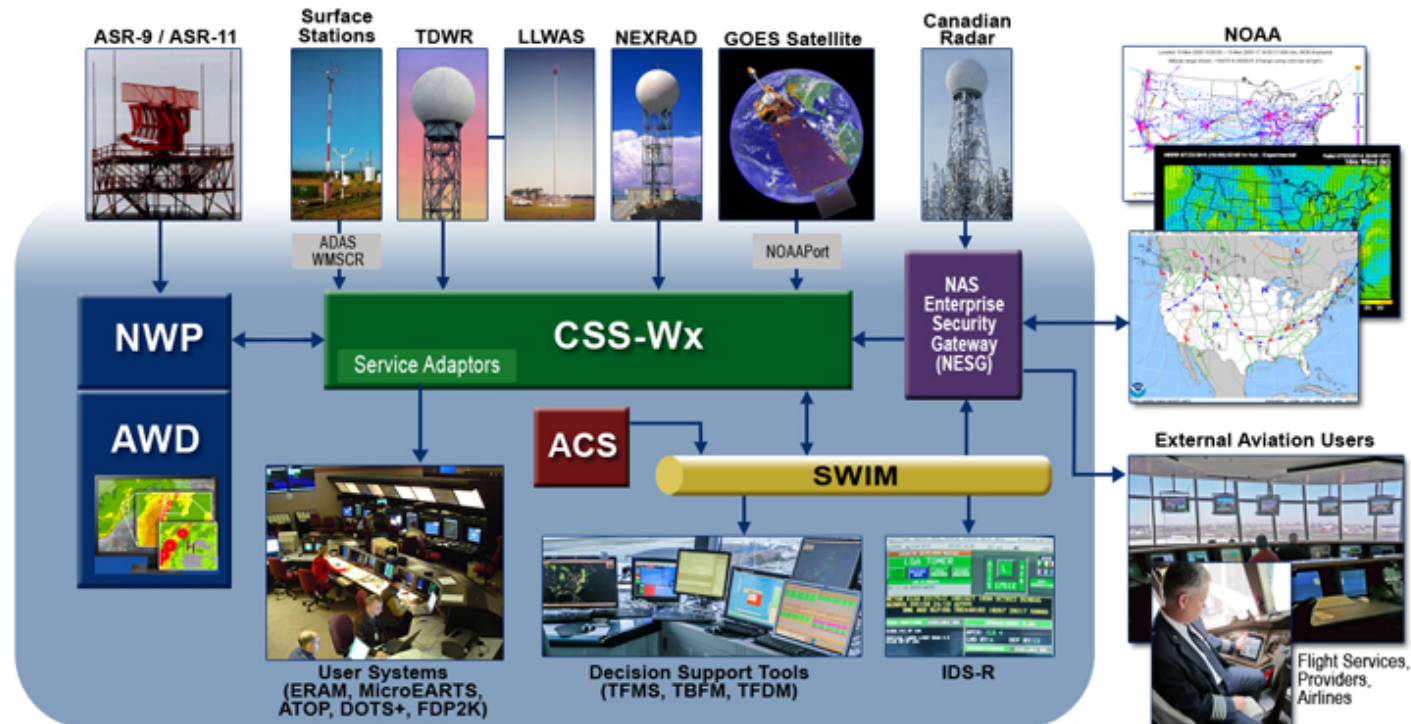
Gust Front Impact Timer indicates when most imminent gust front is expected to arrive at the airport. A purple timer without a number indicates a gust front is on the airport.

Range of coverage for gust front is 60 km from the radar.





# Accessing Terminal Winds, Wind Shear and Precipitation Products with NextGen



- NWP will be generating the ITWS wind products described earlier as well as providing significantly improved precipitation products
- CSS-Wx provides access to all of the NWP products via SWIM
- Current ITWS/CIWS/CoSPA user displays will be replaced by Aviation Weather Display (AWD)



## CSS-Wx/NWP Milestones (as of spring 2016)

Milestone	CSS-Wx	NWP
Final Investment Decision (FID)	March 2015	March 2015
Contract Award*	June 2015	June 2015
Preliminary Design Review (PDR) Completed	March 2016	June 2016
Critical Design Review (CDR) Completed	September 2016	December 2016
Factory Acceptance Test (FAT) Completed	March 2018	February 2019
Operational Test (OT) Completed	November 2018	May 2020
Key Site Initial Operational Capability (IOC)	January 2019	August 2020
In Service Decision	September 2019	April 2021
First Site Operational Readiness Date (ORD)	October 2019	May 2021
Last Site ORD	August 2022	August 2022

- Contract awarded April 2015\*

Key:

Complete

On Track



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# Key Factors in Airport Arrival Rate Setting for GDP Planning

EWR AIRPORT ACCEPTANCE RATE WORKSHEET																		T CLEAR ENTRIES	
TIME	ARR RUNWAYS		FORECAST WEATHER/WINDS				AVAILABLE OVERFLOW				SCHEDULED ARRIVALS			AIRPORT ARRIVAL RATE					
	PRIMARY	OVERFLOW	FINAL APCH SPEED	FIELD COND'S	WIND		MAX TAILWIND COMPONENT		ARRIVAL FIXES		A/C MIX		SCHEDULED ARRIVALS	PRIMARY RWY	O-FLOW RWY	HOURLY TOTAL			
	MIT	MIT			HEADING	VELOCITY	10 KTs	20 KTs	JETS	PROPS	HEAVIES	B757'S							
1100L	A 22L/R	C 11	E 130	F VFR	H 260	I 12	J 5	K 3	ARD	RBV	N 8	O 6	P 42	Q 37	R 8	S 45			
	B 2.75	D 15	LAHSO G NO				12 YES	23 YES	NO OVERFLOW M										

Surface  
winds

Final  
approach  
winds

- A. Primary Arrival Runway
- B. Primary Arrival Runway MIT
- C. Overflow Arrival Runway
- D. Overflow Arrival Runway MIT
- E. Final Approach Speed
- F. Field Conditions
- G. LAHSO –YES/NO Field
- H. Wind Direction
- I. Wind Velocity
- J. 10KT Max Tailwind Component
- K. 20KT Max Tailwind Component
- L. Jet and Prop Arrival Fixes
- M. 'NO OVERFLOW' Check Box
- N. Heavy Jets
- O. B757's
- P. Scheduled Arrivals
- Q. Primary Runway AAR
- R. Secondary Runway AAR
- S. Hourly Total AAR
- T. 'CLEAR ENTRIES' Box

Winds  
aloft

"Compression"

Variables Utilized in Determining Airport Arrival and Departure Rates  
April 6, 2011



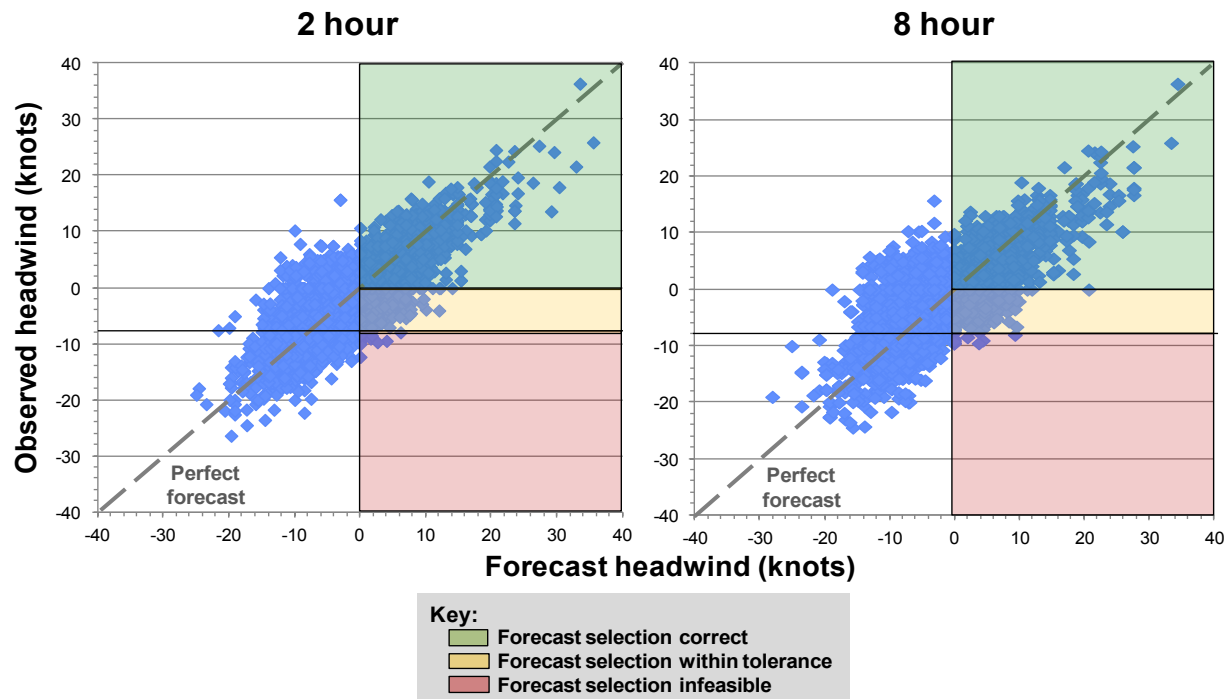
Federal Aviation  
Administration

11



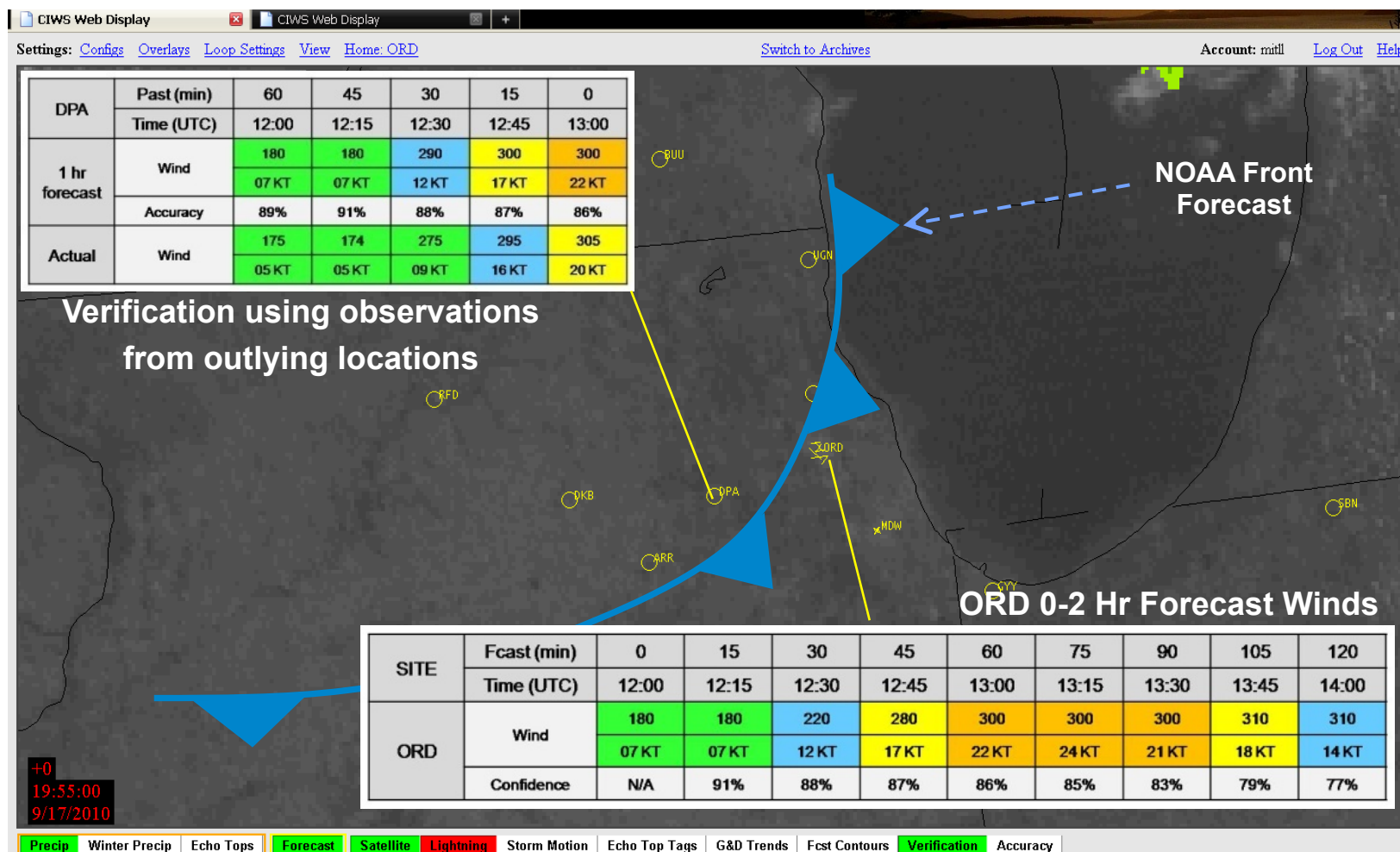
# Wind Forecast Accuracy for GDP Decision Support

- A study of numerical model and TAF wind forecast accuracy for purposes of GDP decision support was conducted for the FAA (Lincoln Laboratory Project Report ATC-414)
- Accuracy for various numerical models (RUC, RAP, HRRR) was similar to the TAF
- Probability of infeasible runway selection was low (<1%), but probability of non optimal runway selection was about 50%
- Timing of significant changes was not assessed --- this is a very important issue





# Display Concept – Surface Winds Forecasts With Real Time Forecast Accuracy Verification

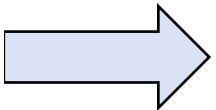




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# Suggested Future Work

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- **Better understand key UAS operator needs through use of wind products in actual operations with ongoing feedback from operational users**
- **Need to reexamine terminal winds accuracy in representative major metropolitan areas in the context of key UTM decisions (e.g., timing and magnitude of significant wind changes)**
  - Key site testing of NWP implementation of ITWS functionality may offer an opportunity for pre 2020 real time usage
- **Improve the 0-2 hour wind forecasts**
- **Develop wind forecast reliability metrics similar to what has been done for strategic traffic flow management in convective weather**
- **Look at downslope wind detection and forecasting for the Ames Nevada UTM test sites**
- **Consider use of non FAA metropolitan area wind sensors (e.g., air pollution wind profilers) as an input to ITWS terminal winds**
- **Develop training and guidelines for relating winds measured at surface (e.g., pole associated with delivery vehicle) to winds aloft at drone flight altitude (see: Siting Guidelines for Low Level Windshear Alert System (LLWAS) remote facilities," FAA Technical Order 6560.21A)**



# Summary

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- **Low altitude winds are important to operation of low altitude UAS**
  - Significant horizontal and/or vertical shear will be a challenge for use of a single surface observation plus HRRR as the sole basis for UTM related wind decision support
  - Safety of the UAS is particularly important in major metropolitan areas
- **Many of the UAS wind operational issues mirror longstanding issues for conventional aircraft operations**
  - Low altitude wind shear and anticipation of wind changes at airports
- **FAA terminal weather decision support systems provide high time/space resolution wind fields plus gust front and wind shear information at 34 major metropolitan areas**
  - Product access for use in UTM will be significantly improved when the NextGen Weather Processor (NWP) is operational
- **Ongoing work to improve FAA strategic and tactical management of wind impacts will often be applicable to UTM operations**



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# Backup Information





## Microburst Observed in Phoenix on July 18 2016

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**Note that the surface winds spread out a long distance from the region of heavy rain at the surface**  
(see the video at <http://mashable.com/2016/07/19/striking-microburst-photo-phoenix/#ohTWSKDA2EqD> )





# CSS-Wx/NWP Implementation

## Common Support Services-Weather (CSS-Wx)

### Current Wx Dissemination:

WARP WINS

CDDS

ITWS Web Server

CREWS

Contract Award: April 2015

**HARRIS**

IOC

ORD

CSS-Wx Work Package 1

### Legacy Wx Dissemination:

WMSCR

ADAS

ALDARS

WIFS

IARD

CSS-Wx Work Package 2

## NextGen Weather Processor (NWP)

### Current Wx Processing:

WARP RAMP

CIWS

ITWS

Contract Award: April 2015

**Raytheon**

IOC

ORD

NWP Work Package 1

IARD

NWP Work Package 2

NWP Work Package 3

CY

2015

2020

2030

2040



# Key Acronyms

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• <b>ADAS</b>	<b>Automated Weather Observing System (AWOS) Data Acquisition System</b>
• <b>ALDARS</b>	<b>Automated Lightning Detection and Reporting System</b>
• <b>CDDS</b>	<b>CIWS Data Distribution Service</b>
• <b>CIWS</b>	<b>Corridor Integrated Weather System</b>
• <b>CREWS</b>	<b>CTAS Remote Weather System</b>
• <b>CSS-Wx</b>	<b>Common Support Services- Weather</b>
• <b>IARD</b>	<b>Investment Analysis Readiness Decision</b>
• <b>IOC</b>	<b>Initial Operational Capability</b>
• <b>ITWS</b>	<b>Integrated Terminal Weather System</b>
• <b>NWP</b>	<b>NextGen Weather Processor</b>
• <b>ORD</b>	<b>Operational Readiness Date</b>
• <b>RAMP</b>	<b>Radar Acquisition and Mosaic Processor</b>
• <b>WARP</b>	<b>Weather and Radar Processor</b>
• <b>WIFS</b>	<b>World Area Forecast System (WAFS) Internet File Service</b>
• <b>WINS</b>	<b>Weather Information Network Server</b>
• <b>WMSCR</b>	<b>Weather Message Switching Center Replacement</b>